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CONVERGENCE IN INDUSTRY EFFICIENCY AND TECHNOLOGY ADOPTION IN AFRICAN TELECOMMUNICATIONS: AN EMPIRICAL STUDY

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Abstract

This analysis is aimed to explore the patterns of convergence in efficiency of telecommunication industry, as well as in adoption of major telecommunication services particularly fixed lines, mobile and internet usage from 2000 through 2009 in 30[1] African Countries. More specifically, it investigates whether: first, there is presence of sigma convergence; that is whether countries which were lagging behind in terms of efficiency in telecommunication industry have been catching up with the better performing countries. Secondly, whether countries have experienced beta convergence; meaning, countries which were less efficient at the earlier time have become more efficient at the later time and overtaken countries which were more efficient at the base year.

Data Envelopment Analysis is used to determine efficiency scores of telecommunication sector across countries and Wilcoxon signed rank and coefficient of variation are employed to test the presence of beta and sigma convergence respectively. In terms of telecommunications efficiency, the study found that countries experienced sigma convergence although at a slower pace, and no evidence for beta convergence except in earlier period, 2000-2001. Regarding telecommunication services, mobile and internet usage exhibited the higher levels of both sigma and beta convergence while fixed lines followed similar trend as industry efficiency pattern. Following these results, it is suggested for policy makers to reduce the the industry efficiency gap by enact incentives to increasing catch-up in efficiency of teletecommunitions industry among countries.

[1] List of African countries included in this study are Algeria, Benin, Botswana, Burkina Faso, Cameroon, Cape Verde, Cote d'Ivoire, Egypt, Eritrea, Ethiopia, Gabon, Ghana, Kenya, Madagascar, Mali, Mauritania, Mauritius, Morocco, Mozambique, Namibia, Niger, Nigeria, Rwanda, Sao Tome and Principe, Senegal, South Africa, Sudan, Togo, Tunisia and Uganda

Keywords: Telecommunications, efficiency, convergence, Data Envelopment Analysis

Introduction

Development of telecommunication sector has widely gained traction as one of the mandatory strategies for social and economic development around the world. Following proliferation of major policy changes in the sector particularly introduction of market liberalization, privatization of the incumbents and establishment of independent regulatory authorities, investments in telecommunication infrastructure have surged across the globe. As results, access and adoption of various forms of telecommunications have increased in most countries. Needless to say, access to basic telecom services is currently widely regarded to be a universal service. Most markedly, the mobile penetration grew from only 12% and 1.5% in 2000 to 87% and over 50% for the world and African continent respectively in just 10 years. Indeed, telecommunications have become the fastest spreading technology in the history of mankind (ITU, 2011).

The African continent was a latecomer both in terms of telecommunication policy reforms and the industry development; nevertheless, the telecommunication sector has benefited in various ways by being the last to develop its telecommunication sector. First, since the continent was the last to undergo reforms in the telecommunications sector, it adopted best practice policies and technologies that had been tested elsewhere. Second, following liberalization of the sector and promotion of regulated competition both in infrastructure and services, most countries were able to attract foreign private investment in the sector led by strategic telecommunication operators that have ample of experience through operations in other countries. These firms had acquired wealth of knowledge, strategies and human resources which could be easily deployed into new markets. In fact as of 2010, six strategic multinational mobile telecommunication operators were controlling 85 percent of all mobile users in the continent. Lasts, according to Moore’s law, rapid advancements in technology renders the cost of electronic equipments to decline sharply in a few years. The opening of telecommunication markets in the continent came when cost of investment especially mobile infrastructures technologies had been affirmed in other markets hence become feasible into African markets. It is expected the African continent should adopt a more efficient telecommunication sector.

World Bank (2009) reports that the adoption of advanced telecommunication services such as broadband, accounts for higher levels of economic growth; where by developing countries benefit more from the similar additional penetration compared to developed nations. Based on economic growth phenomenon, as long as market is yet to be saturated, additional penetration of telecommunications can be attributed to either increasing factors of production – capital and labor, or improving production efficiency (Cronin, Parker, Colleran and Gold, 1991). Therefore to gain the economic growth premium of additional penetration of telecommunication services enjoyed by developing countries, it is in the interest of each country to increase efficiency along with attracting more investment to its telecommunication sector in order to experience higher adoption levels of both basic and advance telecommunication services, and achieve spillover benefits in the economy.

The increasing accumulation of capital, channeling technical communication through involvement of multinational telecommunication firms, and expansion of demand in the telecommunication sector across countries provided social capabilities that render technological catch-up process and convergence of production patterns for countries that were lagging behind (Abramovitz, 1986). These conditions were expected to reduce disparity in production efficiency and technology adoption across countries. Koksi and Majumdar (2000) introduced two fundamental types of convergence into telecommunication industry literature as adopted from income distribution studies. Sigma converges or catch-up process, meaning those countries which were erstwhile less efficient are becoming efficient as erstwhile efficient countries. On the other hand, beta convergence or leapfrogging, meaning erstwhile less efficient have become more efficient than erstwhile better performing countries. Little is known about how the telecommunication sector in Africa has improved its production efficiencies over time, and whether disparities in production efficiencies and adoption of telecom services that used to exist have increased or diminished over time across countries (Koski and Majumdar, 2000). According to the author's knowledge, no study has been conducted to study this phenomenon for African countries.

This paper employs the non parametric approaches particularly Data Envelopment Analysis (DEA) to first analyze efficiency of telecommunications sector in 30 African countries from 2000 to 2009. Then, the results are analyzed to understand the convergence of countries in terms of efficiency scores and three prominent forms of telecommunications namely fixed lines, mobile telecommunications and internet. The results of the study provide a better understanding on the performance and adoption gaps in telecommunication industry among African countries.

The rest of the paper is organized as follows: Section 2 provides literature review, followed by methodology in section 3. Data and the model formulation are presented in the section 4. Section 5 presents the empirical results; and finally, section 6 draws the conclusion.

Literature Review

Due to rapid development of telecommunications industry in the recent years, there has been an increasing interest to investigate productivity and efficiency of telecommunications both at sectoral and firm level. The literature review is confined to studies that focuses on measuring efficiency in the telecommunications sector in cross-regions settings, and its subsequent forms of convergence particularly catch-up and leapfrogging processes.

Early studies in productivity of telecommunication sector relied on parametric approaches particularly estimation of the cost function to estimate productivity changes in the telecommunication sector. Along these lines, Nadiri and Schankerman(1981) estimated productivity growth of the US Bell System from 1947 – 1976 across their state operations using adjusted Divisia index based on estimates obtained from the translog cost function to calculate TFP (Total Factor Productivity). The results of their analysis found that the annual growth rate in the period was 4.09% and large portion of the productivity growth was due to economies of scale.

The adjusted Divisia Index used by Nadiri and Schankerman (1981) suffered from estimation bias since the telecommunications industry is regulated. To correct such bias, Madden, Savage and Ng (2003) employed multi-product multi input Cost Functions for a regulated utility, developed by Fuss and Waverman (1977) to compute Davisia index for TFP estimation. They investigated growth in total factor productivity (TFP) of 12 Asia-Pacific telecommunications carriers for the period 1987 to 1990. The results show that competition, private ownership, technology change and scale economies improve carrier productivity growth. Studies that followed similar methodologies includes Kwaka (1993), Crandall (1991), Denny, Fuss and Waverman (1981), Nadiri and Nandi (1997) and Nadiri and Prucha (1990). Despite the strong foundation of econometric measures of productivity, the approach's statistical reliability greatly depended on the proper specification of the cost function, which is likely to vary among the sample data analyzed; hence vigilant consideration is necessary when adopting such approach.

More recently, productivity literature in telecommunication industry has been extended to analyze convergence and divergence patterns in telecommunications productivity across countries and firms. Perhaps the most common form of convergence found in the literature is the sigma convergence (catch-up process).

Calabrese, Campisi, and Mancuso (2002) used DEA (Data Envelopment Analysis) based Malmquist index and Cobb-Douglas production function to measure evolution of total factor productivity, and labor productivity respectively of telecommunication industry. in 13 OECD countries between 1979 and 1998. With an econometric regression function, the study assessed catch-up (sigma) convergence in productivity among the countries. The results depicted no statistical evidence to suggest catch-up convergence in productivity performance in telecommunication sectors of the countries studied. Madden and Savage (1999) used the DEA based Malmquist Productivity index to assess productivity growth, innovation and catch-up convergence of 74 countries from 1991 to 1995. The study found productivity growth of the telecommunications sector in African countries was declining at -4.7% a year during the above period; and technology catch-up (sigma convergence), together with competition and privatization could improve productivity levels of the lagging countries most of them developing countries.

Mancebon and Lopez-Peuyo (2012) extended the analysis of sigma convergence by analyzing whether the distribution pattern of the productivity scores of telecommunication sectors in analyzed countries remained the same even after detecting presence of sigma convergence. The authors assessed the sigma convergence in the production efficiency of ICT industries in six industrialized countries using DEA approach to compute efficiency scores and kernel density estimation to depict the patterns of sigma convergence for the period from 1979 until 2001. The model results show that while productivity of these countries has sigma converged; there have been intra-distributional changes from a unimodal distribution toward bimodal distributions. The first group constituted countries with high efficiency levels while the second group had lower sector efficiency scores, though with higher efficiency levels than in the earlier years and more closer to the erstwhile efficient countries.

Koski and Majumdar (2001) investigated both catch-up (sigma) and leapfrogging (beta) convergence in 22 OECD countries between 1980 through 1995 in telecommunications sector efficiency and penetration of three main forms of telecommunications services – fixed lines, digitalization and mobile subscribers. Though they used DEA to estimate productivity scores, the study non parametric techniques particularly Wilcoxon Sign Ranked Coefficient and Kendall's W to measure the sigma convergence and beta convergence. It was found that, in telecommunication services the OECD countries had experienced catch-up (sigma) convergence at 8 % per annum, and leapfrogging (beta) convergence in the period under analysis. The study found sigma convergence in the sectors productivity; however, there was no evidence of beta convergence. Battistoni, Campisi and Mancuso (2006) studied harmonization of productivity in Europe by investigating whether the efficiency of telecommunication sector for 10 countries that were allowed to join the European Union on May 2004, had been catching up to the old 15 countries. They study used DEA and stochastic frontier analysis to model efficiency levels, and as Koski and Majumdar(2001), they employed Wilcoxon Sign Rank Coefficient and Kendall's W approaches to assess leapfrogging and catch up effects. Their model found presence of sigma convergence and no evidence of beta convergence in each group, however groups the two groups combined indicated the presence of both sigma and beta convergence.

From the previous literature, it is clear that no assumption can be made on presence of convergence in a group of countries analyzed since there the previous studies have yielded mixed results of convergence in telecommunication industry across countries.

Methodology

Data Envelopment Analysis

Data Envelopment Analysis is a non parametric, deterministic methodology that computes relative efficiencies of entities, called Decision Making Units (DMU), based on the empirical data that consist of the combination of inputs and the resulting outputs obtained for each DMU at a given technology. Using the linear programming equation system, the methodology determines the best performing DMUs which set the production frontier, the efficiency reference indicating the best performance attainable by the DMU's at the given technology. The performance of other DMU's in panel is computed by measuring the distance from the production frontier, therefore indicating their relative level of inefficiency.

As opposed to other methodologies for computing efficiency such as Stochastic Frontier Analysis and Davisia techniques, DEA does not require imposing any functional form of production frontier estimation or any distributional form for the error terms; consequently, misspecifications of the production function are minimized (Carrington et al. 2002). Further, in case of firms, production behaviors such as profit maximization or cost minimization are not specified, they are assumed to be fully reflected in the efficiency scores of each DMU.

Computing DMU's efficiency using DEA can be approached from two different perspectives; particularly, input orientation or output orientation. Input-oriented efficiency is usually adopted when outputs are fixed and inputs are constrained or need to be reduced; while the later is considered when inputs are fixed and the output needs to be maximized. In either case, DEA models can be estimated according to any of the three main scale assumptions: more precisely, constant return to scale (CRS), variable return to scale (VRS) or non-increasing return to scale (NIRS). Whatever orientation adopted, either input or output-oriented, does not change the efficiency level ranking of the DMU; however, when the DMUs are not operating under the assumption of constant returns to scale, efficiency values change when moving from one orientation to another (Calabrese, at al., 2002). Due to regulation and government specific policies imposed on the telecommunication industry, it is unlikely for the industry to operate in optimal conditions that permit constant return to scale. Thus, this study adopts variable return to scale assumption, based on input-oriented DEA model.

To derive variable return to scale DEA model, the constant returns to scale model is first derived, then necessary conditional constraints are applied to achieve VRS model. Based on the constant returns to scale (CRS), Charnes, Cooper and Rhodes (1978) introduced an input-oriented model based on the maximum ratio of weighted outputs to weighted inputs. Assuming there is a data-panel of J DMU's, each with I inputs and R outputs. Hence x_{ij} is the observed amount of the ith input of the jth DMU ($x_{ij}>0$, i = 1,2,…,n, j = 1,2,…,n) and y_{rj} is the observed amount of the rth output of the jth DMU ($y_{rj}>0$, r = 1,2,…,n). Given u_r and v_i as weights for the input and output measure respectively, the following linear programming equation system is employed to determine values for u_i and v_j while maximizing efficiency h_0 for $DMU_{0.}$

$$\max_{u,v} h_0\ (u,v) = \frac{\sum_{r=1}^{s} u_r\, y_{r0}}{\sum_{i=1}^{m} v_i\, x_{i0}}$$

subject to

$$\frac{\sum_{r=1}^{s} u_r y_{rj}}{\sum_{i=1}^{m} v_i x_{ij}} \leq 1, j = 1,2, \dots, j_0, \dots, n$$

$$u_r \geq 0, r = 1,2 \dots., s$$

$$v_i \geq 0, i = 1,2, \dots., m$$

Applied to each DMU, the above linear programming system assigns appropriate weight to each DMU and provides efficiency scores of less than or equal to one. However, this formulation suffers from an infinite number of solutions since if (u^{*}'v*) is a solution, then (αu^{*}, αv^{*}) is another solution and so on. Charnes and Cooper (1962) showed this situation can be treated by imposing the condition for the weighted input, the denominator equal to one, that is

$$\sum_{i=1}^{m} v_i x_{i0} = 1$$

Including the restricting condition to the linear programming problem, the efficiency h_0 for DMU_0 can be written as:

$$\max_{u} z_0 = \sum_{r=1}^{s} u_r y_{r0}$$

subject to

$$\sum_{r=1}^{s} u_r y_{rj} - \sum_{i=1}^{m} v_i x_{ij} \leq 0, j = 1,2, \dots, n$$
$$\sum_{i=1}^{m} v_i x_{i0} = 1$$
$$u_r \geq 0, r = 1,2, \dots, s$$
$$v_i \geq 0, i = 1,2, \dots, m$$

The above linear programming problem can be represented in an equivalent envelopment form in dual as:

$$\min_{\lambda} z_0 = \Theta_0$$

subject to

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0}, \qquad r = 1,2, \dots, s$$
$$\Theta_0 x_{i0} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0, \qquad i = 1,2, \dots, m$$
$$\lambda_j \geq 0, \qquad j = 1,2, \dots, n$$

When the above formulation, based on constant return to scale assumption, is implemented where DMU are not operating at an optimal level, the technical efficiencies tend to be confounded by scale efficiencies. According to Banker, Charnes and Cooper (1984), to adjust the above formulation to reflect variable return to scale assumption, the convexity constraint is imposed on the linear programming formulation by the following condition:

$$\sum_{j=1}^{n} \lambda_j = 1$$

When the above restriction is added into the constant return to scale linear programming problem, the model becomes an input oriented variable return to scale DEA model, referred to as BCC-model after Banker, Charnes and Cooper (1984).

$$\min_{\lambda} z_0 = \Theta_0$$

subject to

$$\sum_{j=1}^{n} \lambda_j y_{rj} \geq y_{r0}, \qquad r = 1,2, \dots, s$$
$$\Theta_0 x_{i0} - \sum_{j=1}^{n} \lambda_j x_{ij} \geq 0, \qquad i = 1,2, \dots, m$$

$$\sum_{j=1}^{n} \lambda_j = 1$$

$$\lambda_j \geq 0, \quad j = 1,2,\ldots,n$$

Solving the above system of linear programming equations yields Θ, which is the technical efficiency score for DMU_0. The process is iterated J times to obtain the technical efficiency for each DMU_j (j = 1, 2… n). Since the technical efficiency, Θ, for each DMU_j in confounded to the restriction $\Theta \leq 1$, the DMUs with technical efficiency equal to 1 form the production frontier, thus technically efficient (Farrell, 1957).

Measuring Convergence

Sigma convergence

To assess the presence of sigma convergence, the coefficient of variation is used, given by the ratio of standard deviation to mean measured at different times. According to Williamson and Fleming(1996:349-350), coefficient of variation is a more preferred measure of convergence than other measures particularly variance and standard deviation due to its ability to account for changes in the mean. Thus, the coefficient of variation shows the degree of variability tied to the mean value. The coefficient of variation on a single period provides little meaning; however, its changes over times indicate whether sigma convergence occurs. More specifically, the rate of convergence between two different years can be given as:

$$\mathbf{MC/year} = \frac{(\mathbf{CV_{t1}} - \mathbf{CV_{t2}})}{\mathbf{CV_{t1}} * (\mathbf{t2} - \mathbf{t1})} * \mathbf{100}$$

Where by MC/year = mean convergence per year, CV_{t1} = coefficient of variation in the earlier date, CV_{t2} = coefficient of variation at the later date, t1 = the earlier date, and t2 = the later date.

The rate of convergence is measured by the mean average per period of measurement; hence, the greater the coefficient of variation over a specified period of time, the greater the magnitude of sigma convergence among countries.

Beta Convergence

Following Koski and Majumdar (2000) and Calebrese et. al. (2006), Wilcoxin signed-rank coefficient, a non-parametric statistics has been adopted for assessing the presence of beta convergence.

The Wilcoxon signed-rank coefficient – based on median – measures whether there has been an intra-distributional change among ranking of countries from earlier time to the later time. In order to detect beta convergence in the sample as the telecommunication sector develops, this procedure is conducted each year against the base year, and in this case the base year is 2000. The Wilcoxon Signed Rank Coefficient is given as follows:

$$\mathbf{Z = \frac{W - \mu_W}{\sigma_W}}$$

where

$$\begin{cases} \mathbf{W} = \sum_{\mathbf{i=1}}^{\mathbf{n}} \mathbf{R_i^{(+)}} \\ \mathbf{\mu_W} = \dfrac{\mathbf{n(n+1)}}{\mathbf{4}} \\ \mathbf{\sigma_W} = \sqrt{\dfrac{\mathbf{n(n+1)(2n+1)}}{\mathbf{24}}} \end{cases}$$

where

n is number of countries yielding non-zero absolute difference between subsequent years

$\mathbf{R_i^{(+)}}$ is the ranking of differences between base year and year i

Data and Model

Data used in the analysis consist of 30 countries in Africa for the period from 2000 through 2009. Data covering annual observations were primarily taken from the ITU Telecommunication database – 2009. For data validation and filling data gaps in the data panel accessed from ITU, World Bank Public Private Investment (PPI) – 2010 database was also used. Nevertheless, due to unavailability of data in multiple years, countries such as Burundi and Somalia have been omitted from the analysis.

To measure efficiency in telecommunications industry, a DEA model was specified comprising of two input variables: total investments in telecommunications and total number of staffs employed by telecommunications industry. The total number of staff refers to all full time employees of the telecommunication operators for each year in each country. In case part time employees are present, their contribution is converted into the equivalent of full time employees (ITU, 2003). Similar studies by Koski and Majumdar (2000), Battistoni et a (2006) and Symeou (2011), investment in telecommunications is used as a proxy for capital that is used to acquire, maintain and upgrade the telecommunications infrastructure that supports services rendered by the industry. To account for inflation, investment in telecommunications (measured in millions) was taken at 2009 prices.

Choice of output variables was based on the interaction between firms and policy makers. While for firms, revenue is important to remain profitable and able to invest in advanced technologies; policy makers are more geared towards goals such as affordability of the services and universal service hence telephone subscriptions and internet users (Giokas et al, 2008). Against this background, this study had included three output variables to reflect the goals of both parts: firms and policy makers. Applying DEA methodology over competing alternatives particularly Stochastic Frontier Analysis, is its ability to accommodate multiple outputs.

Henceforth, the model consists of three output variables, namely total telephone subscriptions, internet users and revenues. Total telephone subscriptions include both fixed lines and mobile subscriptions. Although fixed lines and mobile subscription could stand as two individual variables, this study followed Lam and Shiu (2008) and Giokas et al (2008)'s procedure. The procedure is desirable to reduce the number of variables and allow variability whenever the study includes a small number of DMUs (Coelli, Prasada-Rao and Battese, 1998). While total telephone subscriptions include large portions of basic communication, especially in African countries, it is important to capture the level of advanced telecommunications as outputs similar to Symuou (2011) and Koski and Majumdar (2000). The number of internet users was used to reveal the adoption of advanced telecommunication technologies as one of the output indicators.

Total revenue in the telecommunication industry (measured in millions USD) was used to capture the sector productivity which includes earnings from direct provisions of the telecommunication services to the public excluding revenues of resellers (ITU, 2003). This indicator has been used as the main output in most studies (see Giokas et al, 2008, Lien and Peng, 2001, Lim and Shiu, 2011) as is more suited for industries with a large number of services, which are delivered in significant quality differences (Christensen et al. 2003).

Table 1: The descriptive data of both input and output variables

	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Investment (in millions USD)										
Mean	287	435	564	722	894	1147	1434	1772	2109	2395
SD	694	984	1153	1341	1443	1708	2116	2635	2974	3416
Min	2	3	7	9	11	13	14	15	15	15
Max	3692	5086	5798	6669	6669	6669	6994	9767	11443	14560
Staff (in thousands)										
Mean	7320	7234	7057	7247	7390	9018	9786	10259	10522	11000
SD	13389	12893	12179	12056	12154	16057	20781	22130	22829	25046

Min	108	97	95	93	89	87	86	81	74	70
Max	54922	54810	53108	53108	54759	69120	102935	107623	112194	126552
Subscribers (in thousands)										
Mean	1080	1421	1836	2230	3214	4967	6804	8838	11371	14008
SD	2689	3333	4024	4711	5787	8902	11276	13496	16756	20136
Min	5	5	8	12	15	19	26	38	57	72
Max	13301	15711	18546	21681	25689	38689	44304	46832	64297	75937
Internet users (in thousands)										
Mean	142	193	303	414	650	1007	1401	1707	2538	3678
SD	437	528	651	796	1155	2011	2498	3090	5202	8741
Min	4	6	9	12	14	20	22	23	25	27
Max	2400	2890	3100	3283	4000	9026	9867	12850	23982	43989
Revenues (in millions USD)										
Mean	476	498	525	756	969	1246	1492	1820	2118	2216
SD	1306	1192	1135	1684	2117	2901	3580	4268	4791	5322
Min	6	5	7	8	10	10	11	12	13	14
Max	6830	6197	5826	8917	11172	15498	19161	22901	25415	28740

Source: ITU World Telecommunications Indicator and Public Private Partnership Database World Bank

The results of the above DEA model are then analyzed by the methodology proposed to assess the presence of both catch-up and leapfrogging convergences. To further investigate the phenomenon, convergence is tested on the three telecommunication services indicators, specifically the penetration of main lines, mobile penetration and percentage of internet users.

Empirical Results

Convergence in efficiency of the telecommunication industry

Table 2 shows the descriptive results of the DEA model, and sigma and beta convergences in the telecommunication industry in African countries. As it can be seen, the coefficient of variation has been declining at an average rate of 1.1 percent per year. This means the efficiency of the telecommunication industry in Africa "sigma-converged" to each other over the period of the study. Hence, countries which were less efficient iwith regard to the telecommunication industry in 2000 have been catching up to countries which were more efficient as measured to their ability to transform capital and labor into telephone subscription, internet users, and industry revenue.

Table 2: Results of σ and β convergence of the efficiency of the telecommunication industry

Year	DEA Model Descriptive Statistics		Convergence Statistics	
	Mean	Standard Deviation	Sigma convergence	Beta convergence
			Coefficient of Variation	Wilcoxon Z (Compared to 2000)
2000	0.729533	0.259019	0.355	
2001	0.806267	0.241737	0.300	2.555[R,*]
2002	0.785433	0.228139	0.290	1.867
2003	0.765633	0.237458	0.310	0.731
2004	0.720767	0.262154	0.364	0.547
2005	0.6893	0.246477	0.358	1.271
2006	0.6809	0.247873	0.364	0.901
2007	0.7292	0.244699	0.336	0.121
2008	0.702967	0.246118	0.350	0.36
2009	0.752667	0.240823	0.320	0.628
AV. CON			0.011	

[R, **] means that H_0 hypothesis can be rejected at the 0.01 level, and [R,*] means that H_0 hypothesis can be rejected at the 0.05 level

The results from the Wilcoxon signed rank test suggest that the African countries have not experienced beta convergence with statistical significance with regard to the efficiency of telecommunication industry from 2000 through 2009. That is, the countries' ranking in terms of efficiency of telecommunication industry has remained almost the same throughout the period 2000 – 2009. Hence, countries with efficient telecommunication industry have remained to be the most efficient among other countries in Africa from 2000 through 2009. However, the initial period, 2000 – 2001, was the only time with statistically significant rearrangement in the order of country ranking in terms to efficiency in telecommunication industry among countries.

Hence, the results on convergence of the efficiency of telecommunication industry from 2000 to 2009 suggest two findings: first, though at a small pace, countries have caught-up to each other; and second, the ranking of countries in terms of efficiency in the telecommunication industry, have remained the same, hence no leapfrogging.

Convergence in adoption of telecommunication services

The results on sigma convergence for fixed line penetration, mobile penetration and percentage of internet users among 30 countries in the African continent are shown in table 3. As it can be seen, the coefficient of variation for fixed line penetration – which is the oldest form of telecommunication infrastructure in the study – generally declined across the period of study, although not every year. More specifically, from 2000 until 2004 the sigma convergence increased and decreased from one year to another; however, since 2005 there has been a stable decline in the coefficient of convergence, indicating an increasing sigma convergence. Further, countries seem to have "sigma-converged" in fixed lines penetration at a marginal rate of only 0.7 percent per year. In case of mobile penetration, countries started at a lower base of sigma converge in the base year with coefficient of variation at 1.671, the highest level of divergence among all three forms for technology penetrations in the study. Nevertheless, countries have experienced an average sigma convergence of 7.6 percent per year, the fastest decline in coefficient of variation compared to other forms of telecommunication services penetration. As for internet users, the coefficient of variation has decreased from 1.575 to 1.001 from the base year to the last year of the study respectively, depicting an average sigma convergence rate of 4.04 percent per year.

Table 3: Results on measures of σ and β convergence in penetration rates of main lines, mobile subscriptions and internet users per population

Year	**Main lines per 100 persons**		**Mobile subscriptions per 100 persons**		**Internet users per 100 persons**	
	Sigma convergence	Beta convergence	Sigma convergence	Beta convergence	Sigma convergence	Beta convergence
	Coefficient of Variation	Wilcoxon Z (Compared to 2000)	Coefficient of Variation	Wilcoxon Z (Compared to 2000)	Coefficient of Variation	Wilcoxon Z (Compared to 2000)
2000	1.423		1.671		1.575	
2001	1.438	3.199 R,**	1.469	-4.541 R,**	1.452	-4.784 R,**
2002	1.434		1.305	-4.703 R,**	1.277	-4.783 R,**
2003	1.457	2.4 R,*	1.160	-4.703 R,**	1.184	-4.782 R,**
2004	1.440	2.51 R,*	1.048	-4.782 R,**	1.135	-4.782 R,**
2005	1.445	2.585 R,**	1.011	-4782 R,**	1.067	-4.782 R,**
2006	1.432	2.52 R,**	0.883	-4.782 R,**	0.953	-4.782 R,**
2007	1.391	3.003 R,**	0.743	-4.782 R,**	0.938	-4.783 R,**
2008	1.361	3.034 R,**	0.585	-4.782 R,**	1.039	-4.782 R,**
2009	1.358	3.116 R,**	0.526	-4.782 R,**	1.001	-4.782 R,**

AV. CON	0.007		0.076		0.04	

R,** means that H_0 hypothesis can be rejected at the 0.01 level, R,* means that H_0 hypothesis can be rejected at eh 0.05 level

Given the stagnant penetration of fixed lines penetration in African countries at approximately 2 percent in the period of study, it is not surprising that sigma convergence among countries was not experienced meaningfully in the first five years of the study, and the average sigma convergence per year throughout the period of study was only 0.7 percent. On the other hand, the number of mobile subscriptions in the 30 African countries increased by almost 13-fold during the period of the study. Consequently, countries have experienced greater catch-up convergence in mobile subscription; in fact the highest level of sigma convergence. This implies that, sigma convergence is likely to occur on when the penetration of technology grows, and likely to remain the same, or change only marginally when penetration levels remain stagnant.

Further, table 3 provides results of sigma convergence in three forms of telecommunications: fixed lines penetration, mobile penetration and percentage of internet users. The null hypothesis in this analysis – H_0 stated, there is no beta convergence among the countries between the base year and the year i. As it can be seen, based on the Wilcoxon signed Rank coefficient Z, the hypothesis was rejected for all forms of telecommunication, however with varying degree. The Wilcoxon signed rank coefficient Z for fixed lines between base year and all years was rejected; however, between 2000 and 2002, 2003 and 2004, the results were slightly weak statistically. This implies that, while there was beta convergence in the early years between 2000 and 2004, the convergence was statistically weak; after 2004 the beta convergence became statistically significant. On the other hand, for both mobile penetration and the percentage of internet users, the hypothesis has been rejected at the highest level of statistical significance in every year of the study. This implies that countries have experienced leapfrogging as the ranking of each year have statistically changed from ranking observed in the base year ranking for penetration in all forms, with weak evidence in fixed line penetration.

Discussion

The results of the analysis show that in terms of efficiency in the telecommunication industry, countries managed to “sigma-converge” to each other from 2000 to 2009. That is countries which were less efficient have been able to catch up to the more efficient countries at a rate of only 1.1% per year. In case of adoption of the growing telecommunication services particularly mobile subscription and internet services, higher catch-up pace was observed among countries, at annual average rate of 7.6 % and 4 %

respectively. Comparing the rate of average sigma convergence between industry efficiency vis-a-vis adoption of the most growing services – mobile penetration and internet usage, sigma convergence grew slower in terms of telecommunication industry efficiency compared to mobile services penetration and internet usage. In other words, countries managed to reduce their differences in terms of penetration rates of mobile and internet usage at a faster rate. The trend was inconsistent and slower in terms of the industry efficiency catch up of less efficient countries to more efficient ones. This suggests that the prevailing telecommunications policies adopted by countries in the African continent have managed to lower the gap among each other in terms of penetration of telecommunication services; however, the gap has been declining slowly and inconsistent with regard to the efficiency in telecommunication industry among countries.

Further, the sigma convergence for mobile penetration and percentage of internet users reveals a somewhat interesting pattern. Starting from the low base of only 141 million internet users in the sample countries, internet users grew almost 26-fold. In fact, adoption of internet usage was the fastest growing service among all forms of telecommunication services in the study. In terms of mobile adoption, in 2009 mobile subscriptions was 13-fold of the number of mobile subscriptions in 2000 – fast growth but not as fast as in internet usage. Contrary to growth trend in adoption increases in these two telecommunication services, countries had experienced less average sigma convergence per year in terms of internet users as compared to mobile subscriptions. More specifically, countries experienced an average of 7.6 percent growth of sigma convergence per year with regard to mobile subscriptions, compared to only 4.04 percent with regards to internet users. This suggests that although African countries have experienced fastest growth in terms of internet usage among other telecommunication services, the highest level of sigma convergence was experienced in mobile penetration. Thus, the increase in internet usage was only concentrated in few countries, most likely in the well developed ones. On the other hand, the growth of mobile subscriptions was likely a result of high growth in less penetrated countries as they catch-up to countries with the developed telecommunication industry. This does not mean a lack of technological catch-up with regard internet usage, but rather a slower pace compared to catch-up experienced in mobile subscription.

The presence of beta convergence in the group of DMU's with regard to a particular metric suggest changes in rankings of countries that exhibit best practices within the group. Identification of these countries is imperative for policy makers from countries with similar socio-economic and telecommunication industry characteristics – since these best practices can be studied and adopted by less performing countries. Based on statistical evidence, this analysis shows that countries have experienced strong beta convergence in mobile and internet usage, weak in fixed lines and almost none in efficiency scores from 2000 to 2009. This implies that countries with originally best practices in terms of telecommunication sector efficiency have remained so throughout the study. However, in terms of penetration of internet usage and mobile adoption, countries have exhibited changes in ranking. Hence, leapfrogging or beta convergence was exhibited in mobile penetration and internet usage. Therefore, leapfrogging was only experienced in fast adopted technologies, where countries which previously had less penetration in mobile services and internet usage overtook the originally best performing countries; hence providing new opportunity for policy maker in less penetrated countries to learn the best practices from newly high ranked countries.

Conclusion

As a conclusion, the results of this study suggest three main implications concerning convergence of industry efficiency and adoption of telecommunication services. First, more emphasis should be given to policies that can improve catch-up in efficiency among countries, hence reducing the gap between the less efficient countries and efficient ones. Second, despite the high growth rate of internet usage on the continent beyond any other telecommunication service in the study, it seems to be concentrated in few countries, at least as compared to mobile subscriptions. Thus, similar policy stress should be put on improving adoption of internet services across all countries in the continent, especially those lagging behind. Lastly, as the industry progresses, list of countries that portray best practice have not been static. Therefore, in addition to internal initiatives, policy makers in the lagging countries can benefit by identifying new leading countries with similar socio-economic characteristics and adopt appropriate replicable policies to enhance their telecommunications markets.

Having analysed the trends in convergence of efficiency in the telecommunication industry and subsequent adoption of main telecommunication services – particularly fixed lines, mobile and internet usage further research can be conducted to understand the determinants for an efficient telecommunication sector on the African continent. Such study will further shed light into specific policy options, especially for less efficient countries.

References:

Abramowitz, M., 1982. Catching up, Forging Ahead, and Falling Behind. *Journal of Economic History.* Vol. 46. No. 2. pp. 385 – 406.

Banker, R. D., Charnes, A. and Copper, W. W., 1984. Some models for estimating technical and scale efficiencies in data envelopment analysis. *Management Science.* Vol 30. pp. 1078 – 1092.
Battistoni, E., Campisi, D. and Mancuso, P., 2006. European Integration and Telecommunication Convergence. pp. 357 – 377. In: B. Preissl and J. Muller *Governance of Communication Networks.* Physica-Verlag Heidelberg.
Calabrese, A., Campisi, D. and Mancuso, P., 2010. Telecommunication Industry and Productivity Convergence in the OECD Countries. The University of Rome Tor Vergata http://userpage.fu-berlin.de/~jmueller/its/conf/dub01/papers/mancuso.pdf (January 12, 2013)
Carrington, R. Coelli, T. and Groom, E., 2002. International Benchmarking for Monopoli Price Regulation: The Case of Australia Gas Distribution. *Journal of Regulatory Economics.* Vol. 21. pp. 191 – 216
Charnes, A., Copper, W. W. and Rhodes, E., 1978. Measuring the efficiency of decision-making unit. *European Journal of Operational Research.* Vol. 2. pp. 429 – 444
Christensen L. R., Schoech. P.E. and Meitzen, M. E., 2003. Telecommunications productivity. in G. Madden (ed.) *Traditional Telecommunications Networks.* Chaltenham, UK.
Coelli, T., Prasada-Rao, P. and Battese, G. E., 1998. An Introduction to efficiency and productivity analysis. Boston: Kluwer Academic Publishers.
Crandall, R. W., 1991. "Efficiency and Productivity. pp. 404 – 418. In: Barry G. Cole (ed.), *After the Breakup: Assessing the New Post AT&T Divestiture Era*. New York: Columbia University Press
Cronin, F. J., Parker, E. D., Colleran, E. K., & Gold, M. A., 1991. Telecommunications Infrastructure and Economic Growth: An Analysis of Causality. *Telecommunications Policy.* Vol.15. No.6. pp. 529 – 535.
Denny, M., M. Fuss, and L. Waverman, 1981. The Measurement and Interpretation of Total Factor Productivity in Regulated Industries, with an Application to Canadian Telecommunications. pp. 179 – 218. in Thomas G. Cowing and R. Stevenson (eds.). *Productivity in Regulated Industries.* New York: Academic Press.
Giokas, D. I. and Pentzaropoulos, G. C., 2008. Efficiency ranking of the OECD member stated in the area of telecommunications: A composite AHP/DEA study. *Telecommunications Policy.* Vol 32. No. 9 – 10. pp. 672 – 685.
Koski, H. A. and Majumdar, S. K., 2000. Convergence in Telecommunications Infrastructure Development in OECD Countries. *Information Economics and Policy*. Vol. 12. pp. 111 – 131.
Kwoka, J. E. Jr., 1993. The Effects of Divestiture, Privatization and Competition on Productivity in U.S and U.K. Telecommunications. *Review of Industrial Organization.* Vol. 8. pp. 49 – 61

Lam P. and Shiu, A., 2008. Productivity analysis of the telecommunications sector in China. *Telecommunications Policy.* Vol. 32. No. 8. pp. 559 – 571.

Lien, D. and Peng, Y., 2001. Competition and production efficiency of telecommunications in OECD countries. *Information Economics and Policy.* Vol. 13. pp. 51 – 76.

Madden, G. and Savage, S. J., 1999. Telecommunications productivity, catch-up and innovation. *Telecommunications Policy.* Vol. 23. No. 1. pp. 65 – 81

Madden, G., Savage, S. and Ng, J., 2003. Asia-Pacific Telecommunications Liberalisation and Productivity Performance. *Australian Economic Papers.* Vol. 42. pp.91 – 102

Mancebon, M. and Lopez-Pueyo, C., 2012. A Non-parametric Analysis of Convergence in ICT Industries. *Review of European Studies.* Vol. 4. No. 5. 95 – 109.

Nadiri, M. I., & Prucha, I. R., 1990. Dynamic Factor Demand Models, Productivity Measurements, and Rates of Return: Theory and an Empirical Application to the U.S. Bell System. *Stuctural Change and Economic Dynamics 2.* pp. 263 – 289.

Nadiri, M. I., and Nandi, B., 1997. The Changing Structure of Cost and Demand for the US Telecommunications Industry. *Information Economics and Policy.* Vol.9. pp. 263 – 289

Nadiri, M. I., and Schankerman, M., 1981. pp. 219 – 247.in Thomas G. Cowing and R. Stevenson (eds.). *Productivity in Regulated Industries.* New York: Academic Press.

Symeou, P. C., 2011. Economy size and performance: An efficiency analysis in the telecommunications sector. *Telecommunications sector.* Vol 35. No. 5. pp. 426 – 440.

Williamson, J. B. & Fleming, J. J., 1996. Convergence theory and the social welfare sector: A cross-national analysis. pp. 348 – 355 in: Inkeles, A. and Sasaki, M. 1996. *Comparing nations and cultures.* Englewood Cliffs, NJ: Prentice Hall.